USGS
science for a changing world

An Ex Post Facto Evaluation of Sand Mass Balance in Grand Canyon

Measurements Versus Rating Curves as a Means of Assessing the Value of Adaptive Management

Scott A. Wright, Theodore S. Melis, David J. Topping, and David M. Rubin

October 27, 2005

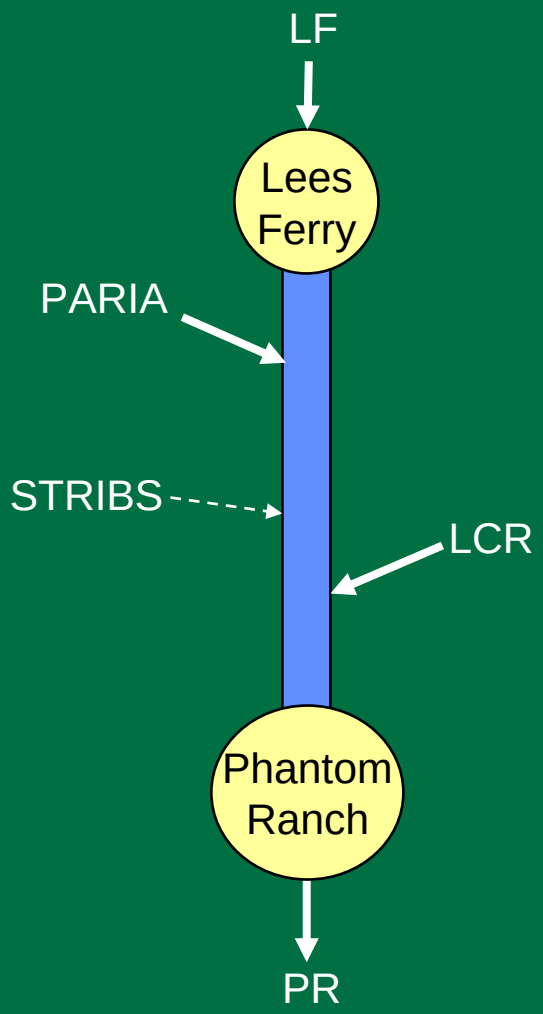
U.S. Department of the Interior
U.S. Geological Survey

Study Objective and Motivation

- **Objective: Compare EIS predictions for sand mass balance to results from our recent intense monitoring program**
- **Motivation: Learn why the EIS predictions seem not be playing out – ensure that the same mistakes are not made in the future**
- **Reinforce the value of post-ROD monitoring and research**

USGS

Sand Mass Balance Definition



Study Reach is from
Lees Ferry to Phantom Ranch

Mass Balance Equation

$\Delta S = LF + PARIA + LCR + STRIBS - PR$

IF $\Delta S > 0$ – Inputs exceed export
Accumulation in reach

IF $\Delta S < 0$ – Export exceeds inputs
Erosion from reach

USGS

EIS Analysis Methods

Sand Transport “Rating Curves”
Sand concentration is a function of discharge only

$$C = aQ^b$$

PARIA: Based on data from 1948 – 1976

LCR: Based on data from 1959 – 1970

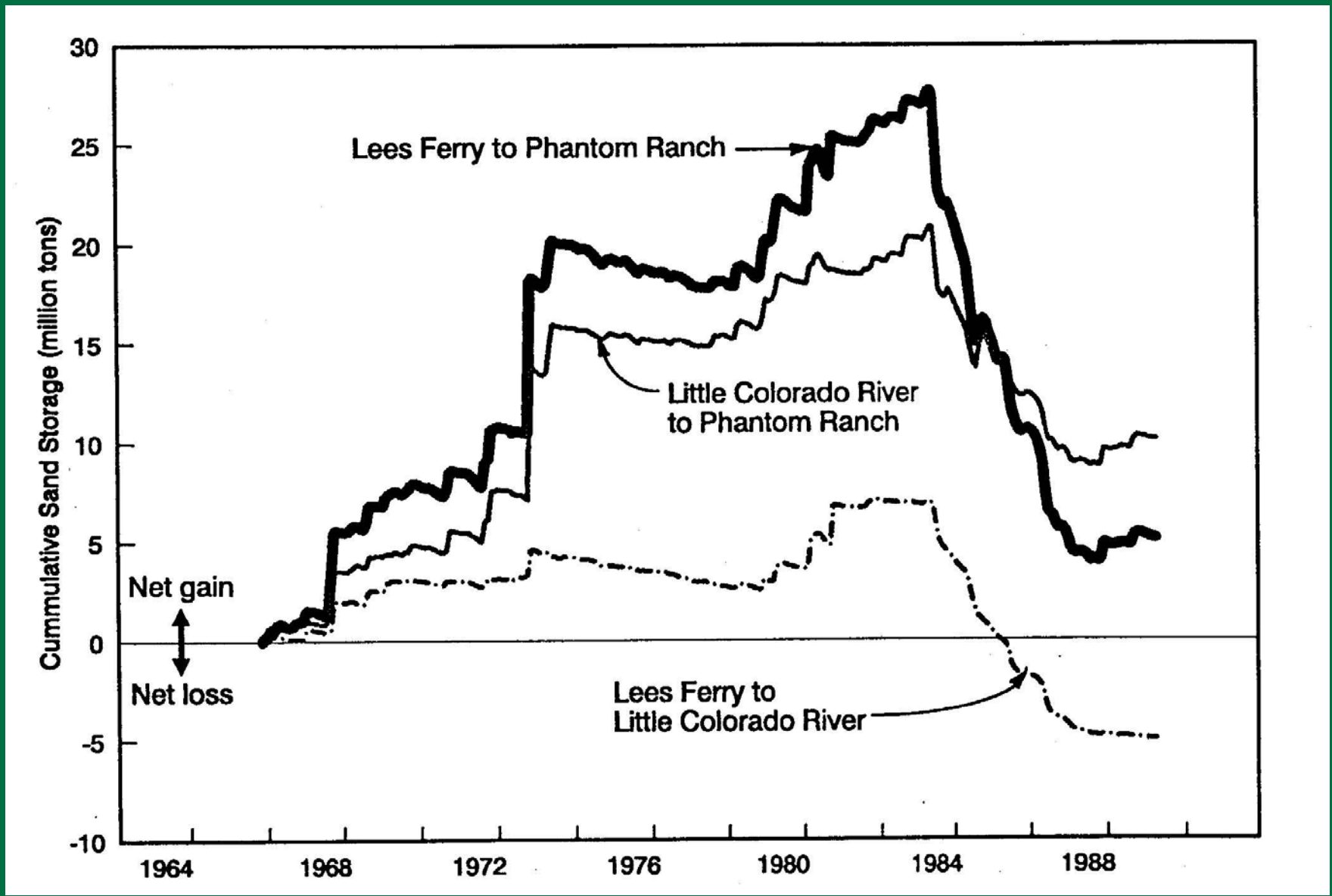
STRIBS: Based on regional relationships

LF: Based on data from 1983, 1985 – 1986

GC: Based on data from 1983, 1985 - 1986

USGS

EIS Sand Budget Result

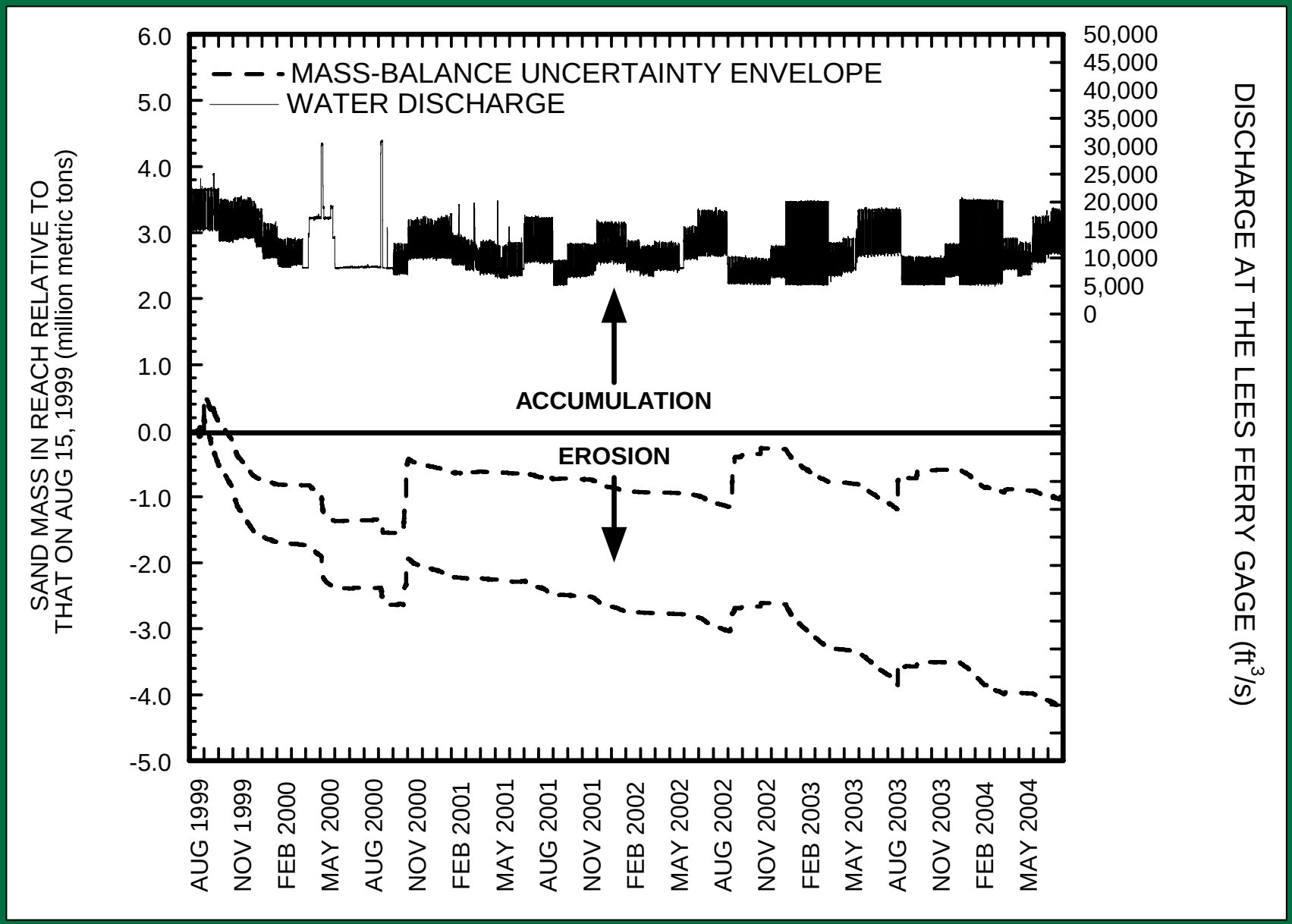


Current Monitoring Program

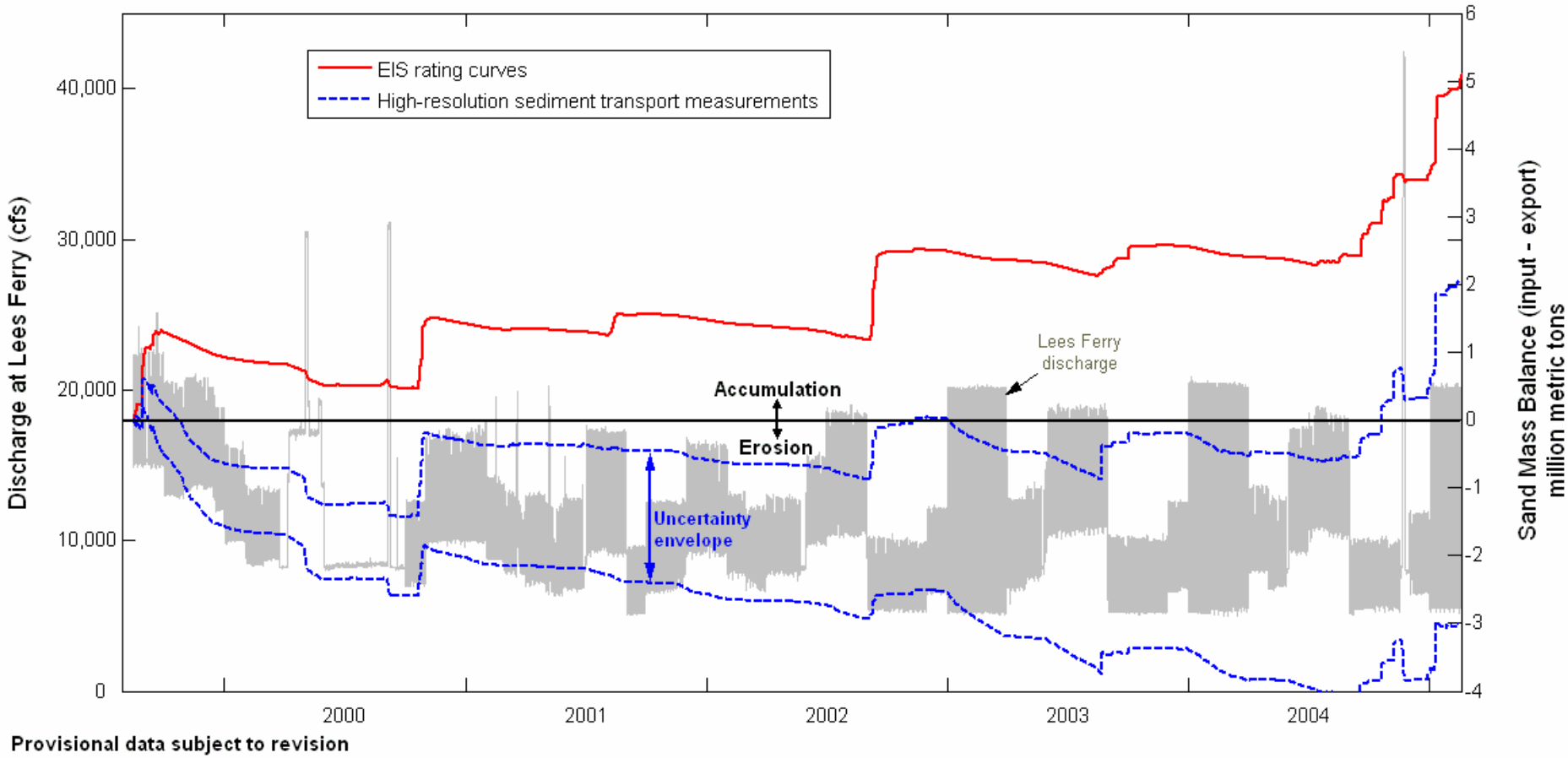
- High flow sediment sampling on Paria, Little Colorado, and several of the smaller tributaries.
- Geomorphic model for the Paria River.
- Combination of sediment sampling and high-resolution surrogate measurements (acoustics and optics) at several mainstem sites.
- Rating curve used for LCR only. Based on and validated with high flow sampling.
- Began in August 1999.

USGS

Current Monitoring Program Results

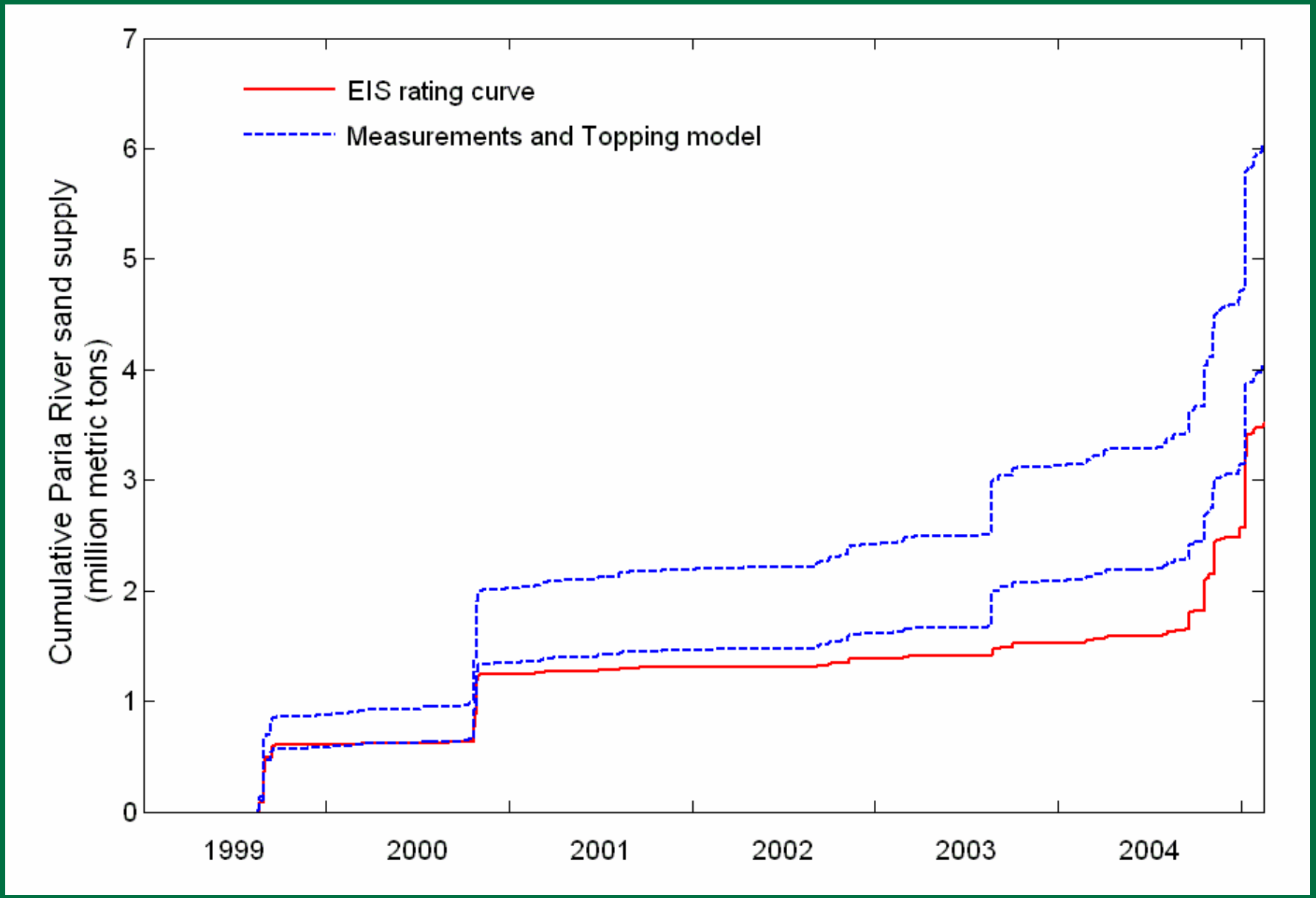


EIS Predictions versus Recent Data

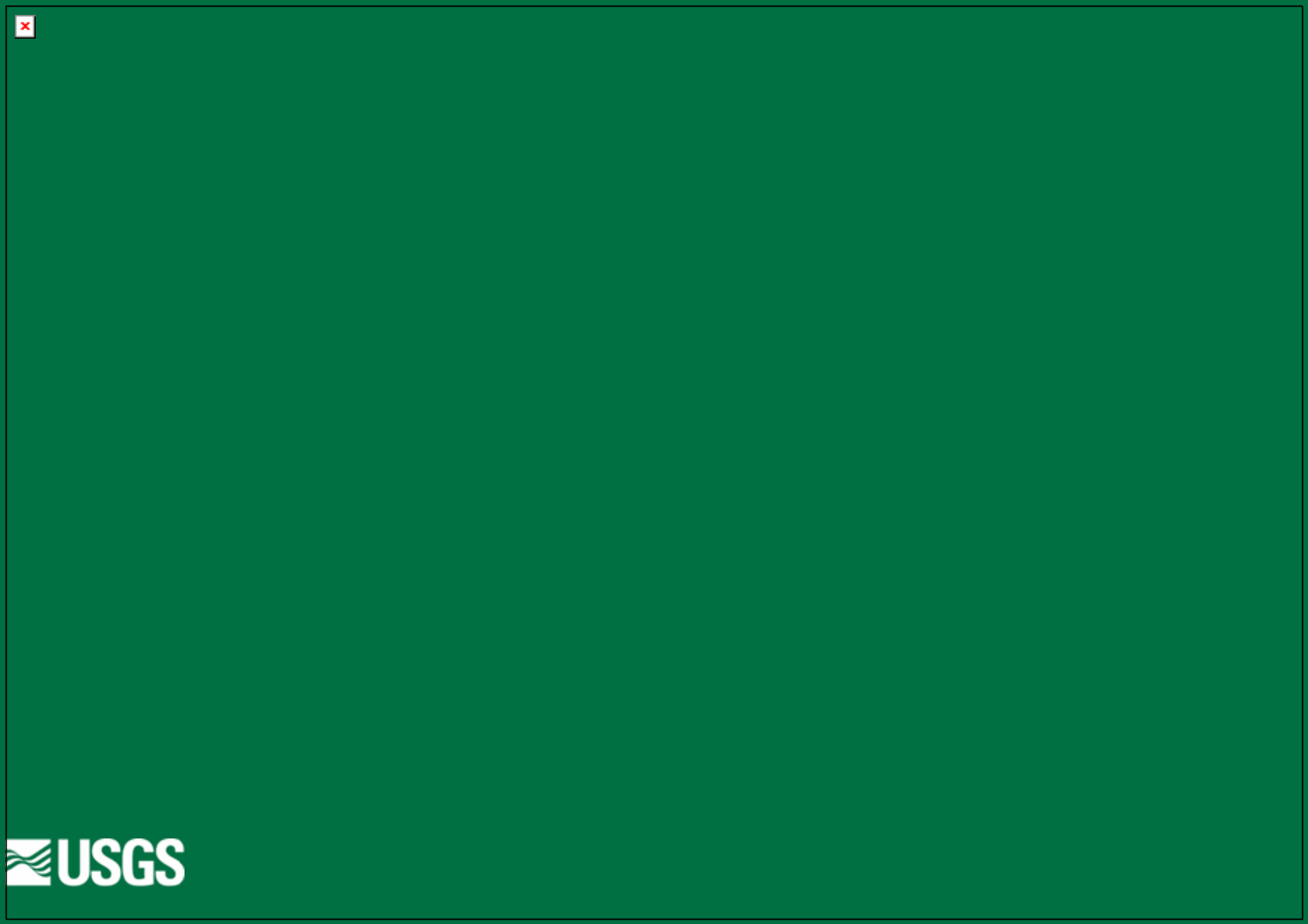


USGS

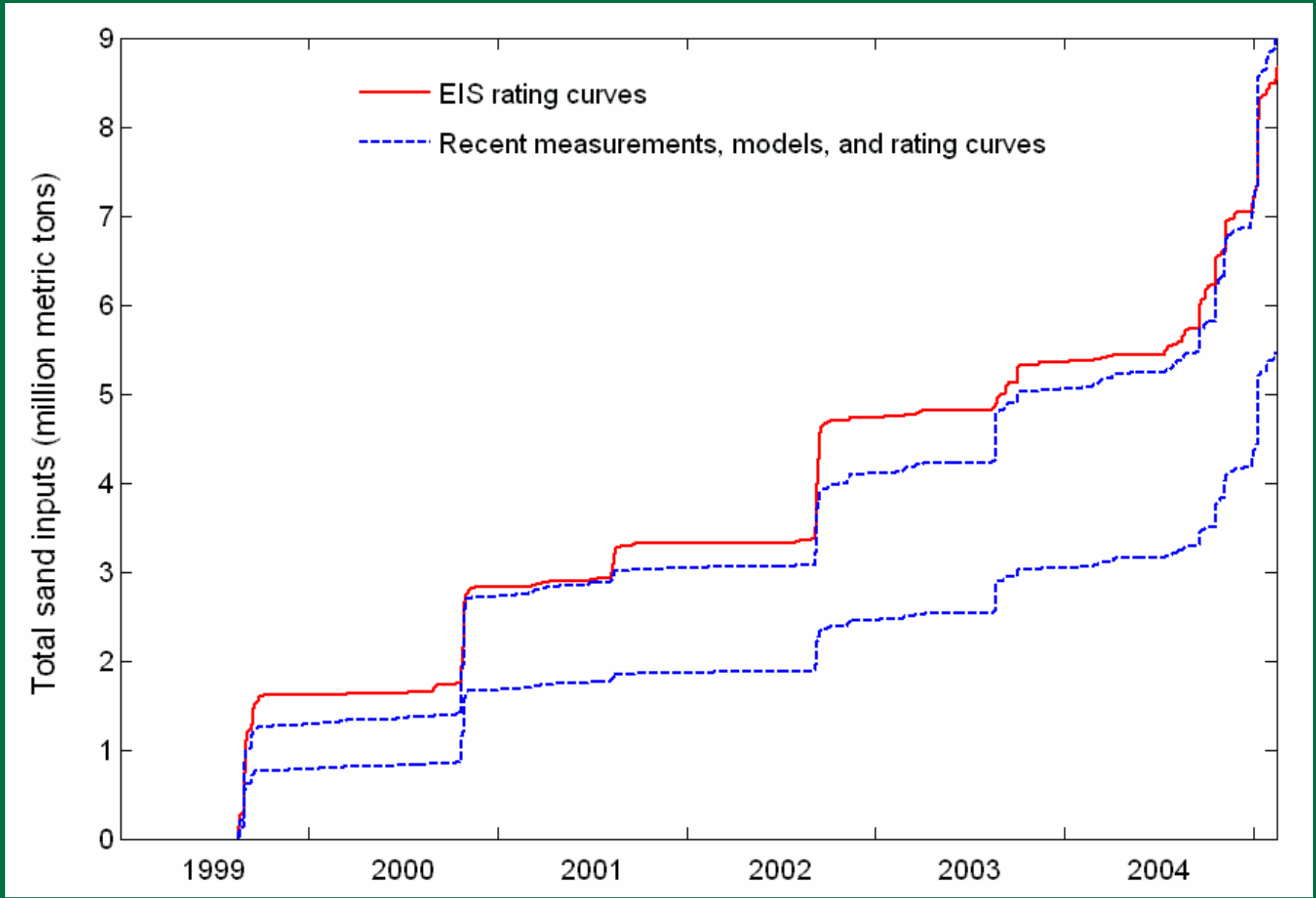
Comparison of Paria Sand Inputs



Comparison of LCR Sand Inputs



Comparison of Total Sand Inputs

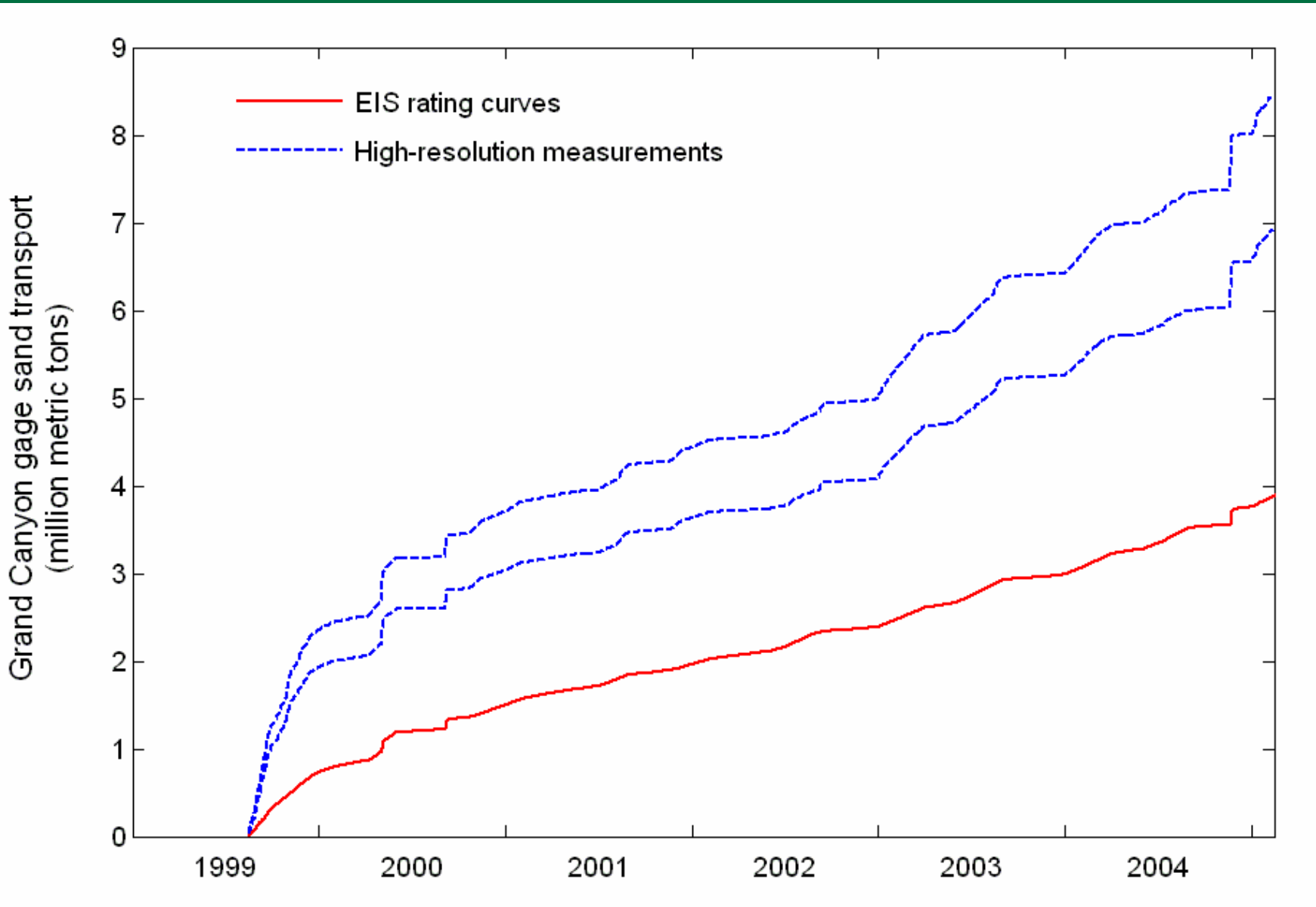


Summary Comparison of Inputs

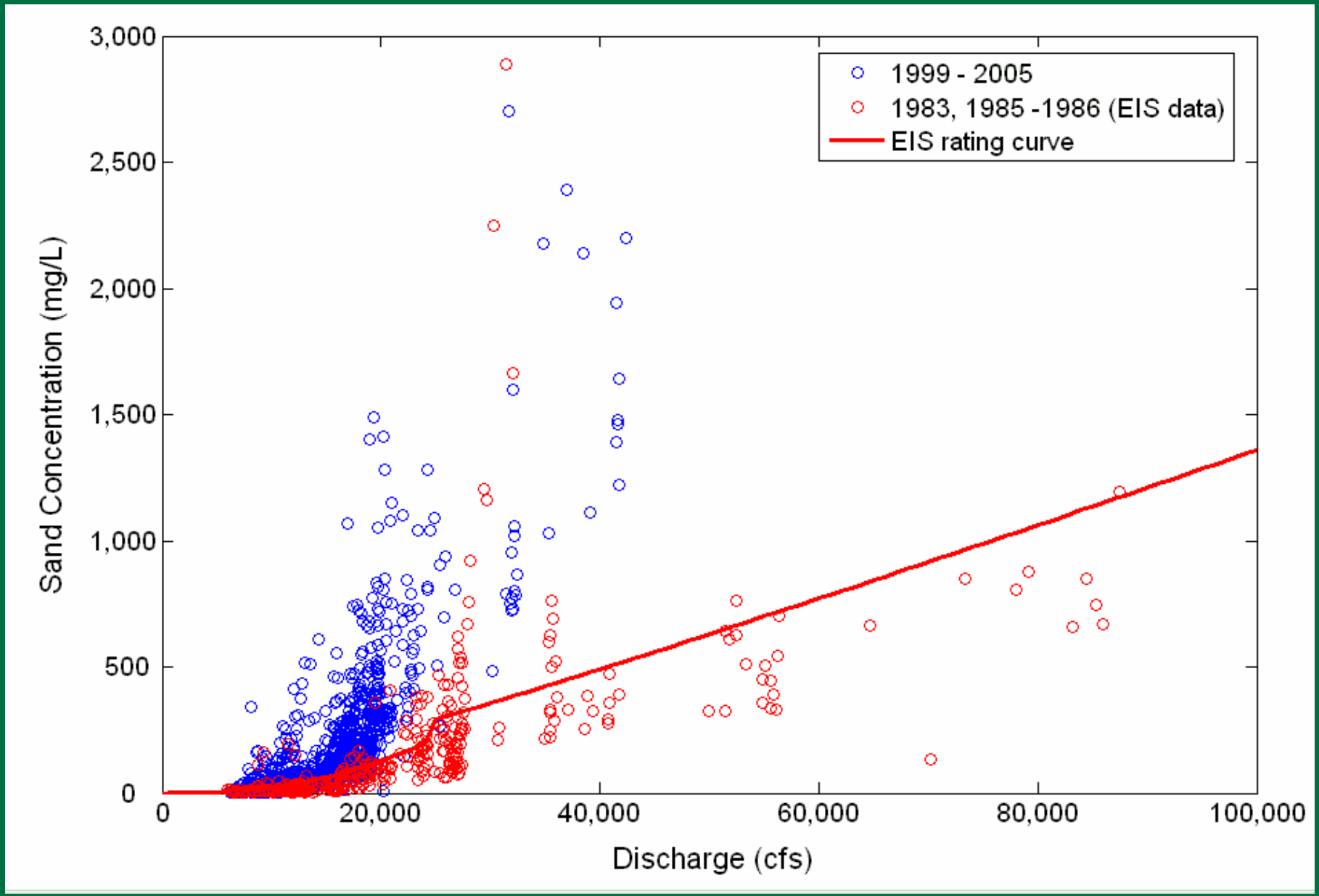
- EIS method under-predicts Paria inputs
- EIS method over-predicts Little Colorado inputs
- In terms of total sand supply to Marble Canyon, EIS predictions are within the uncertainty bound of recent measurements and modeling results

USGS

Comparison of Sand Export



Why the Difference in Export?



Closer Look at Rating Curves

Sand Concentration Relation: $$C = \frac{0.05}{C_f}\left[\frac{HS}{RD}\right]^{2.5}$$

C_f = constant
R = constant
H = flow depth, $H = aQ^b$
S = water surface slope, constant or $S = cQ^d$

Applying these assumptions: $$C = \alpha Q^{\beta}\left(\frac{1}{D^{\delta}}\right)$$

Rating curves only valid if sand grain-size does not vary

USGS

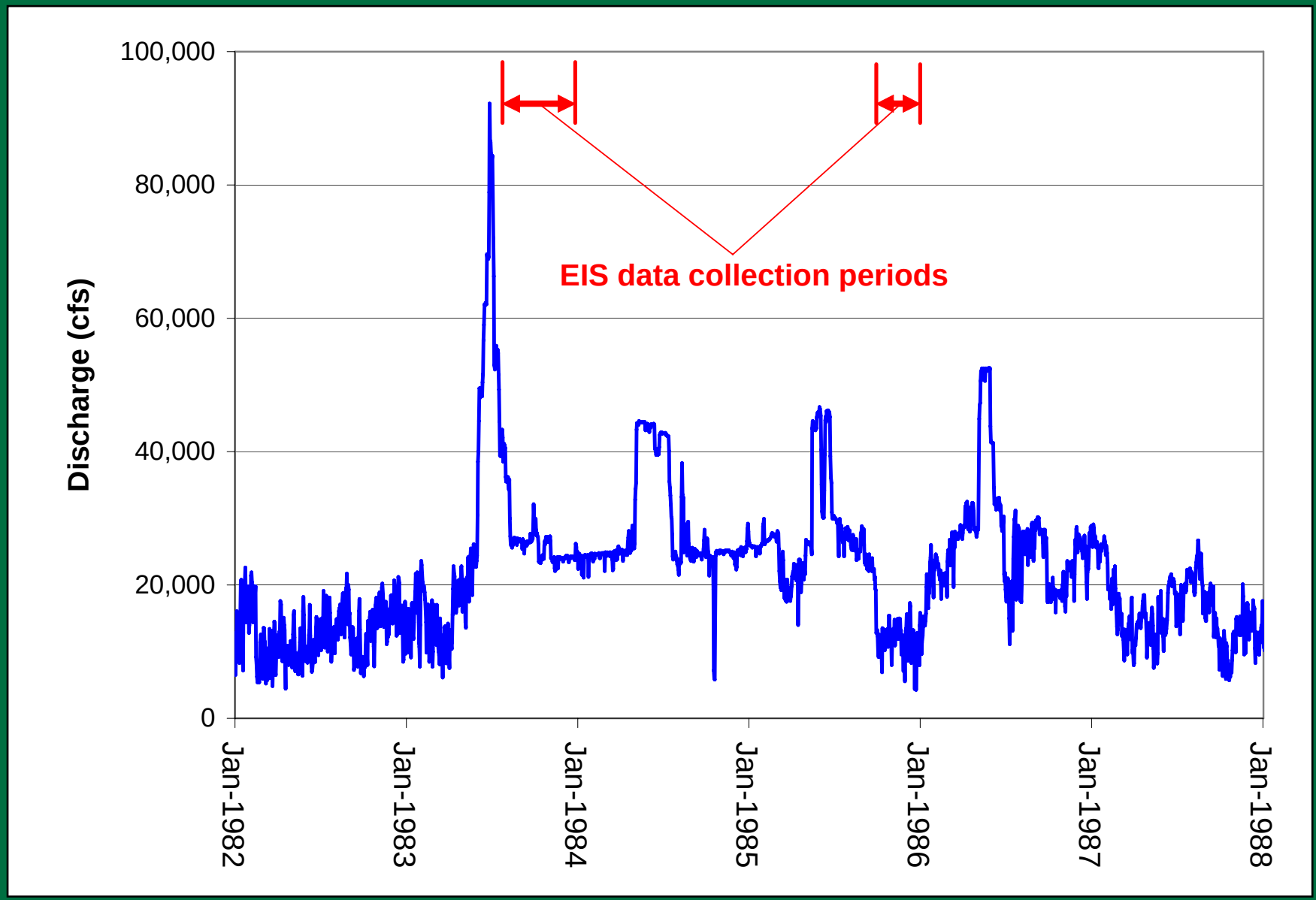
Sand Grain-Size not Constant

Reach is supply-limited.
Grain-size of sand on the bed depends on recent history of flows and inputs.

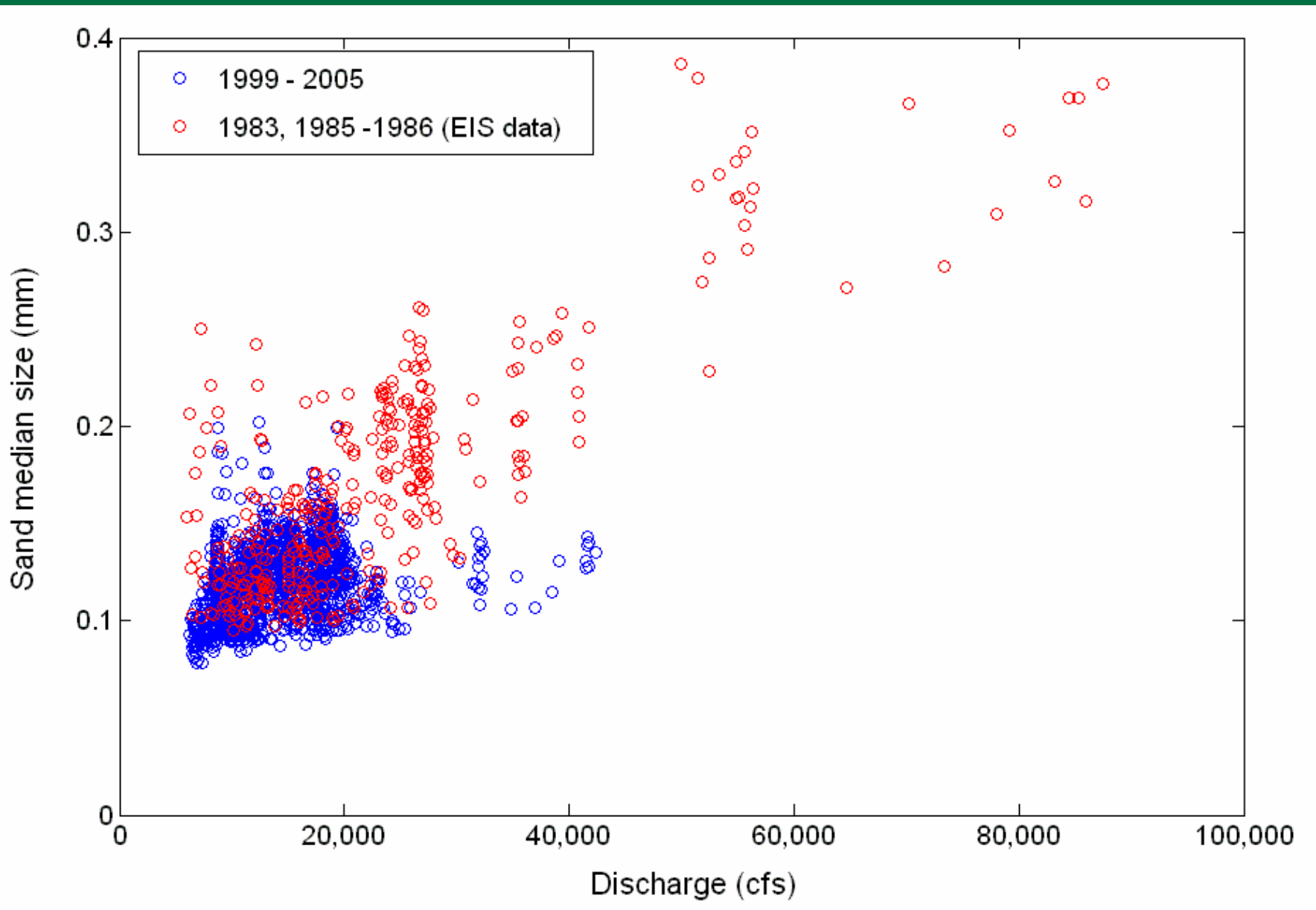
- **System was anomalously coarse in mid-1980s due to very high flows – EIS data collection period.**
- **Tributary inputs cause short-term fining of the bed.**

USGS

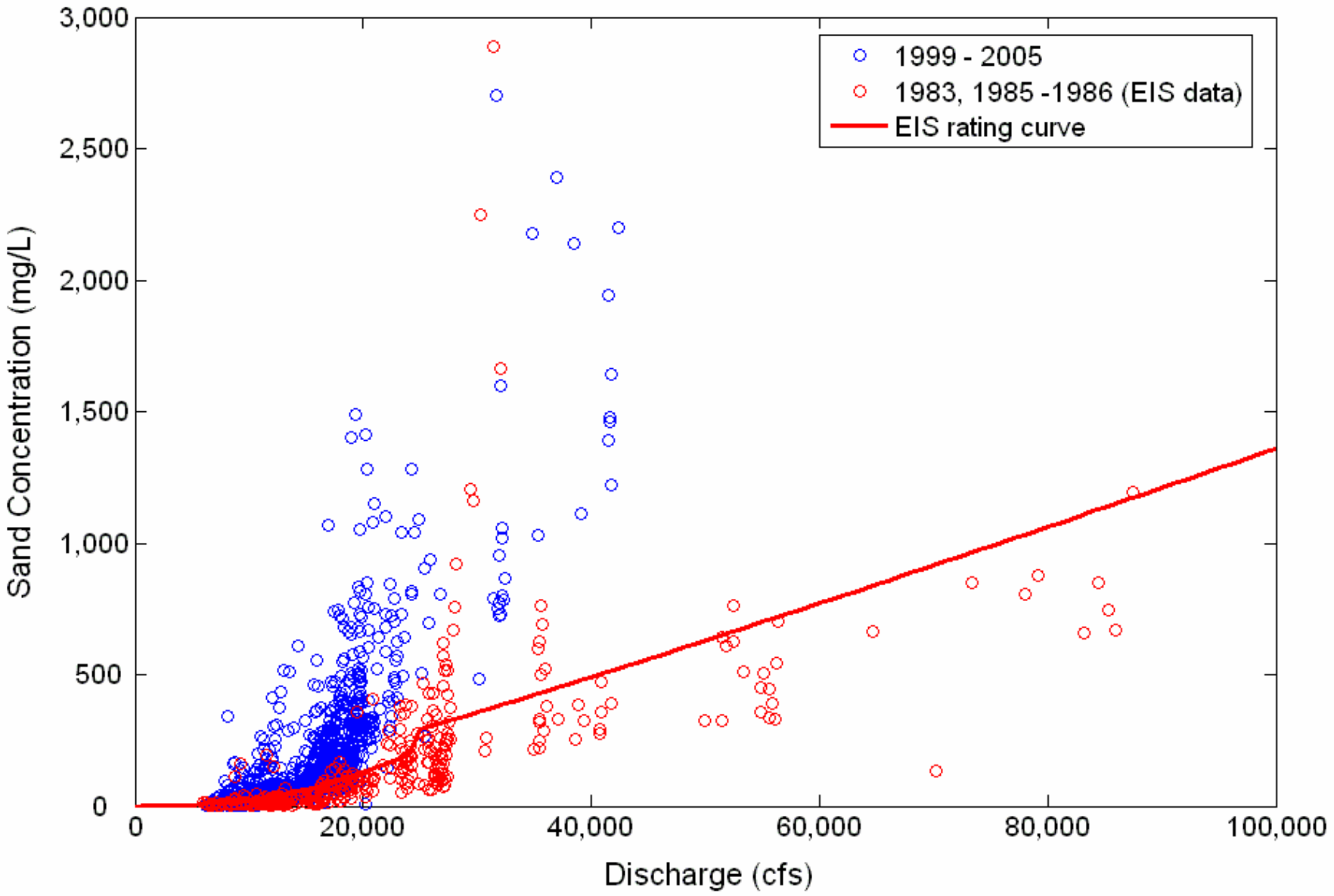
Mid-1980s Flows and EIS data



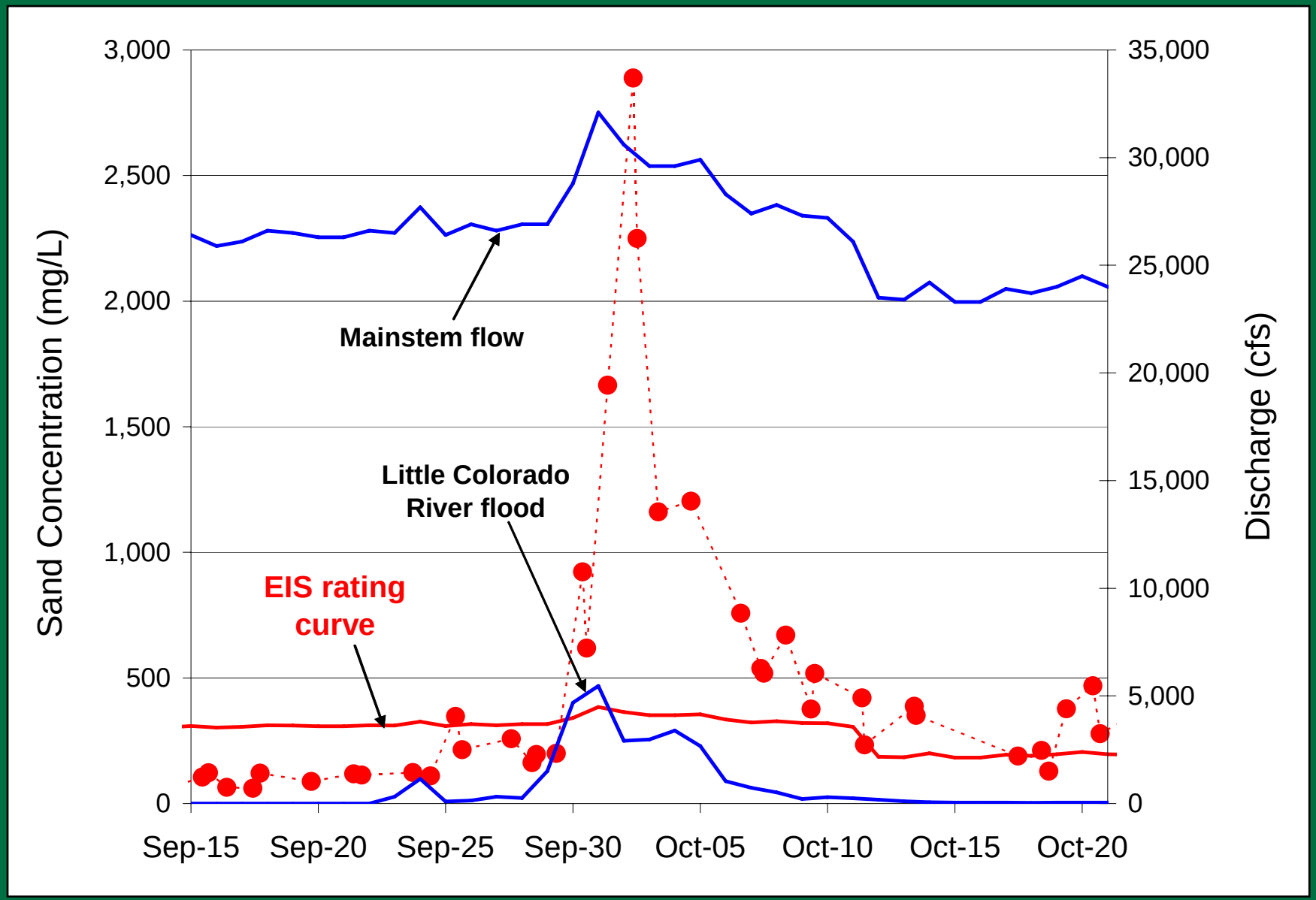
Suspended Sand Very Coarse in 1980s



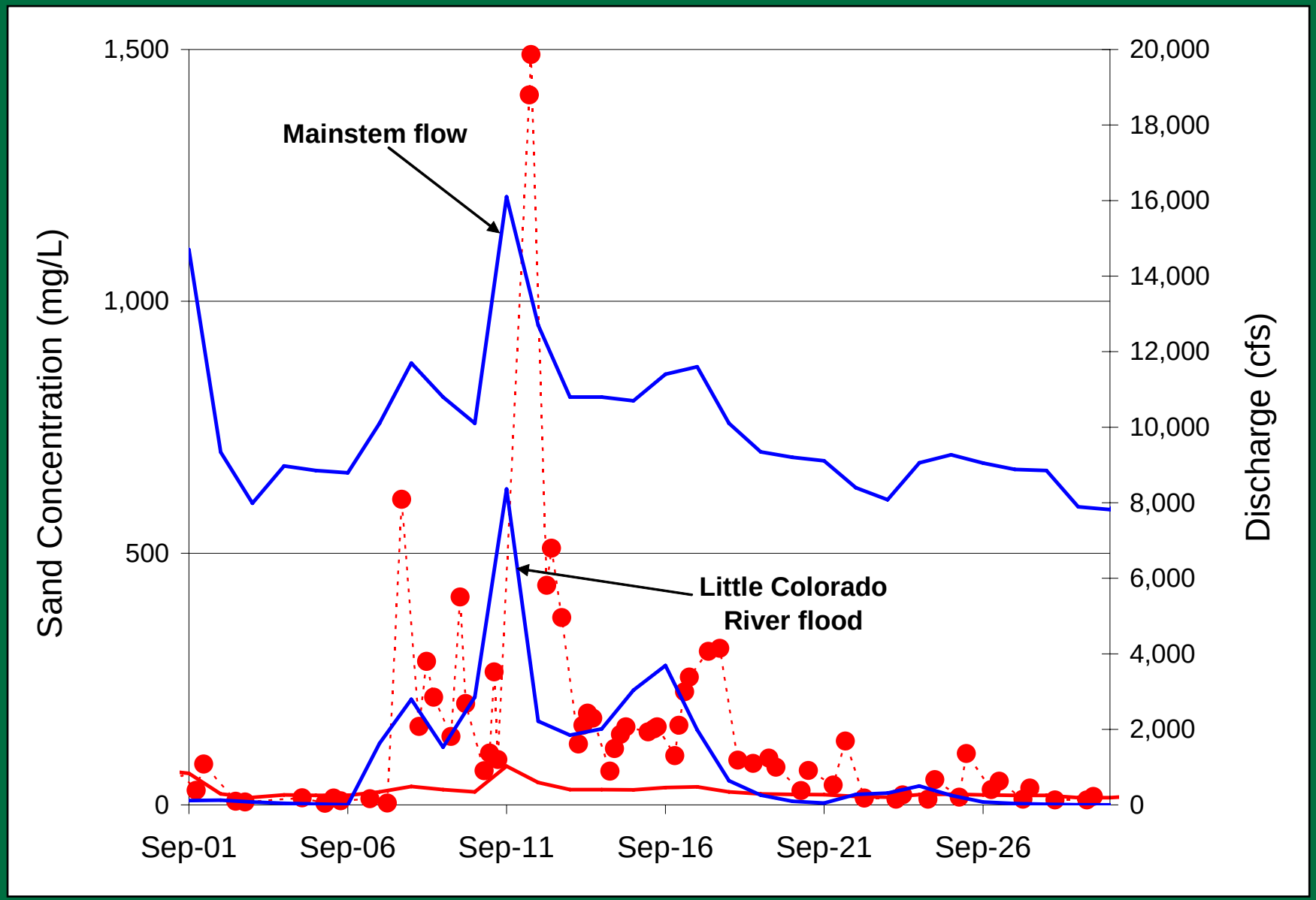
When Coarse, Concentration is Less for a Given Discharge



Bed Fining During Tributary Inputs - 1983



Bed Fining During Tributary Inputs - 2002



Summary and Conclusions

- EIS method (rating curves) cannot account for changes in the grain-size of sand on the bed. Since large changes do occur, results in major under-prediction of mainstem transport
- Data was available, particularly the 1983 LCR flood, for the EIS team to make this interpretation
- High-resolution monitoring required to capture the variability resulting from changing grain-size
- Post Record-of-Decision monitoring is essential for evaluating the success of the preferred alternative and for contributing to adaptive management.

USGS